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TITLE
METHOD DEVICE FOR HEATING FLUIDS

INVENTORS
THOMAS JOHNSTON
TIMOTHY VAUGHN

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Lisa Gentry
Name of Person Filing or Mailing Document

Lisa Gentry
Signature of Person Mailing or Filing Document

BACKGROUND OF THE INVENTION

Reference to Related Application

[0001] This present application claims benefit from U.S. Provisional Patent Application Serial Number 60/432494 filed December 11, 2002 in the names of Thomas Johnston and Tim Vaughn entitled "Method and System for Rapid Heating of Ultrapure Liquid."

Field

[0002] The system and method of the present invention pertains to the field of heaters for fluids; more particularly, the inline heating of a fluids in a confined space without introducing contaminates to the fluid being heated.

Background

[0003] Heated ultrapure fluids are used for a variety of reasons. For example, hot fluids are required during several processing steps in the manufacture of an integrated circuit. It is typically impractical to first heat the fluids and then purify it and, because of the miniaturized scale of microcircuits and the critical manufacturing tolerances required in their production, virtually any impurity in the etching or rinsing fluid can result in defective parts and, consequently, wasted resources. Accordingly, it is preferable to start with a pure fluid and then heat it to the desired temperature.

[0004] Traditional heat exchange systems are unable to meet the demands of today's integrated circuit manufacturing process. For example, in a coil heat exchanger, a long,

small diameter tube is placed concentrically within a larger tube, the combined tubes being bent or wound in a helix. A fluid of one temperature passes through the inner tube, and a second fluid of another temperature passes through the outer tube. The heat exchanger can be configured so that the liquid in the inner tube heats or cools the liquid in the outer tube or vice versa. This type of heat exchanger is generally capable of handling high pressures and wide temperature differences. Although these exchangers tend to be quite inexpensive, they tend to be quite large, they provide rather poor thermal performance because of the small heat transfer area, and they are antagonistic to ultrapure liquids.

[0005] Another traditional heat exchanger, the shell-and-tube type heat exchanger, consist of a bundle of parallel tubes that provide the heat transfer surface separating two fluid streams. The tube-side fluid passes axially through the inside of the tubes while the shell-side fluid passes over the outside of the tubes. Baffles external and perpendicular to the tubes direct the flow across the tubes and provide tube support. The shell-and-tube exchanger is efficacious in certain circumstances but has severe limitations in connection with integrated circuit processing, including the large size of the exchanger, thermal inefficiency and general intolerance for ultrapure liquids.

[0006] Heater manufacturers have sought to design devices acceptable for integrated circuit manufacturing which are thermally efficient, responsive to fluid flow changes, and capable of long life. For example, in order to maintain the purity required in integrated circuit processing filtering processes are employed to remove contaminants and de-ionize the fluid. Heat exchange systems are also generally designed to prevent contact between the contaminant-free fluid and any substance that would tend to corrode in the presence of the

fluid, causing impurities to be reintroduced. Although most plastic materials tend to be good thermal insulators and therefore seemingly inappropriate for some uses in heating systems, most modern heaters for use in microchip manufacturing systems must employ plastics barriers to prevent the contaminant-free fluid from contacting the metallic heating element, lead wires and the like.

[0007] The prior art teaches a number of techniques for heating ultra-pure liquids. For example, in U.S. Pat. No. 4,461,347, issued Jul. 24, 1984, Layton *et al.*, teaches immersing a heat source within a stream of the fluid to be heated. In this process, the heating element is contained within a non-reactive material to prevent contamination of the fluid. Heat is transferred to the fluid by conduction. As the heat from the heat source increases, the likelihood of contamination increases. Layton also teaches that the non-reactive sheath is preferably a plastic such as polytetraflouroethylene or polypropylene, both of which are thermally insulative, thereby reducing the efficiency of the transfer of heat to the fluid.

[0008] In U.S. Pat. No. 4,797,535, issued Jan. 10, 1989, Martin teaches heating a fluid by immersing a tungsten-halogen bulb in the fluid within a vessel, such as a pipe. As the fluid passes the bulb, heat transfers to the fluid. Martin does not appear to contemplate ultra-pure fluids, and no precautions are taken or taught for maintaining the purity of the fluid.

[0009] In U.S. Pat. No. 5,054,107, issued Oct. 1, 1991 Batchelder teaches a system for heating ultra-pure fluids. In particular, a quartz spiral or double walled tube is configured to surround several high intensity lamps. The fluid to be heated flows through the quartz tube. The lamps are not immersed in the fluid but radiate energy (infrared) outward through

the tube and the liquid. The construction is wrapped in aluminum foil to reflect radiation that passes beyond the tube back through the fluid.

[0010] It is well recognized that the operative life of lamps of this type is greatly diminished as a result of high temperature operating conditions. Batchelder appears to recognize this and discloses a fixture for removing heat from the ends of the bulbs. Nevertheless, Batchelder teaches that up to twelve lamps can be mounted within the center of the quartz tube. These lamps will necessarily heat one another, thereby reducing the effective lifetime for the system, requiring more frequent routine maintenance for lamp replacement.

[0011] In U.S. Pat. No. 5,790,752, Anglin, *et. al.* teach a system for heating ultrapure liquids utilizing one or more elongated lamps that generate infrared radiation as the heating elements. In particular, the infrared lamps surround a vessel made of quartz through which liquid that is to be heated is passed. A quartz vessel, such as tubing, can be expensive and difficult to form into the desired configuration. In addition, the mass of the quartz present also absorbs some percentage of the infrared energy and keeps that amount of energy from being absorbed by the liquid being heated.

[0012] Accordingly, there exists a need for non-contaminating fluid heating systems which can efficiently and economically heat and maintain the fluid passing therethrough at a desired temperature. Further, a fluid heater is needed which is durable and capable of long, sustained use in harsh environments. Moreover, a fluid heater and control system is needed for preventing damage to the heater components and for ensuring that the fluid will be heated only to temperatures within acceptable limits. The present invention fulfills these needs and provides other related advantages.

SUMMARY

[0013] This present invention is for a fluid heater that is suitable for heating ultrapure fluids. The heater is useful in any application requiring an ultraclean, non-contact method of raising the temperature of a liquid or gas such as in the semiconductor industry, in heating circulating chemical baths, or in the medical industry for heating recirculated blood or heating medical gases.

[0014] The preferred system utilizes one or more lamps that generate infrared radiation as the heating elements. Fluid to be heated is passed through a vessel such as a tube. The vessel, formed of PFA or polytetraflouroethylene, is coiled around the lamp or lamps. A chamber surrounds the lamp or lamps and the vessel. A temperature sensor at the outlet end of the vessel sends a signal to a controller that adjusts either the flow of fluid through the vessel or the intensity of the lamp or lamps, thereby controlling the fluid temperature at the outlet.

[0015] One advantage of the present invention over the prior art is the elimination of the need for the use of a quartz vessel to hold the fluid, thereby reducing cost in acquiring and manufacturing the quartz vessel. Another advantage of the present system is that there are no coated metals in the heater core, thereby eliminating the possibility that the coating will degrade or flake over time and add impurities to the fluid. Yet another benefit is the ease of servicing the heater due to the wide availability of PFA tubing.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

[0016] A better understanding of the system and method of the present invention may be had by reference to the drawing figures, wherein:

FIG. 1 shows a side view of the chamber for the heater of the present invention.

FIG. 2 shows an end view of the heater of the present invention.

FIG. 3 shows a cross section view of the chamber of the preferred embodiment.

DESCRIPTION OF THE EMBODIMENTS

[0017] FIG. 1 shows a side view of the preferred chamber **100** for the present invention. An inlet end **101** to the vessel and an outlet end **102** to the vessel protrude from the chamber **100**. It will be apparent to one of ordinary skill in the art that the material used to make the chamber should be lightweight and easy to mill but solid and durable for withstanding the rigors of processing such as, for example, aluminum.

[0018] The chamber **100** can be made of any material, however, there are advantages to making the interior of the chamber, or coating the interior of the chamber, with a material that reflects radiant energy. Because the radiant energy source **103** is located in the center of a coiled vessel **104**, the energy is directed radially outward from the source. The reflective material on the inside of the chamber **100** reflects the radiant energy back toward the vessel **104**, thereby providing additional heating capability to the vessel **104**. The reflective material may be any of those known in the art, such as gold, polished aluminum, stainless steel or nickel plating. Accordingly the reflective material should be highly reflective of the radiation wavelength produced by the radiant energy source **103**. The shape of the chamber

100 can be rectangular, as shown in FIG. 1, cylindrical, square, or any other configuration that will accommodate the radiant energy source **103** and vessel **104** discussed below.

[0019] The fluid to be heated enters the vessel **104** through the inlet end **101** and exits the vessel **104** through the outlet end **102**. The inlet end **101** and outlet end **102** are preferably formed of an inert or nonreactive material to prevent contamination of the fluid. As is well known, the inlet end **101** and the outlet end **102** can be integrally formed with the vessel. The inlet end **101** and the outlet end **102** must each pass through an aperture in the wall of the chamber or through the end cap. Any convenient location for the apertures can be used.

[0020] FIG. 2 shows an end view of the preferred chamber **100** for the present invention. A vessel **104** is coiled around a radiant energy source **103**. The radiant energy source **103** can be, for example, an infrared lamp or lamps but should have a wavelength at least as long as infrared. If the radiant energy source **103** is more than one lamp, the lamps can be configured in any of a number of different ways to optimize the energy emitted from lamps with respect to the vessel **104**. The radiant energy source **103** is held in the chamber **100** by its ends, either by an attachment to the end plates of the chamber **100** or by an attachment to the vessel **104**. The wavelength of the radiant energy source **103** may be adjusted to optimize performance so as to enhance efficiency of heat transfer to the fluid to be heated. Under certain circumstances, lamps having different operating characteristics can be selected to accommodate heating fluids having widely variant heat absorption properties.

[0021] The vessel **104** used to carry fluid to be heated is formed of an inert or non-reactive material to avoid contaminating the fluid. According to the preferred embodiment,

the vessel **104** is formed of perfluoroalkoxy or polytetraflouroethylene. The size of the vessel **104** may vary. In the preferred embodiment, the chamber **100** size is no larger than 24 inches by 24 inches by 8 inches, the length of the vessel **104** within the chamber **100** is approximately 22 feet and the vessel **104** is capable of holding approximately 120 milliliters of fluid. The size of the vessel **104** can be adjusted in order to accommodate differing flow rates. Because the vessel **104** is coiled around the radiant energy source **103**, the fluid remains in a heat exchange relationship with the fluid for a substantially longer time than if the vessel **104** ran substantially parallel to the radiant energy source **103**. It is desirable that all the radiant energy produced by the lamps impinge onto the fluid to impart the greatest heating efficiency. Accordingly, the vessel **104** need not be coiled in a single layer around the radiant energy source **103** but that subsequent coils may overlap earlier coils. By doing so, those coiled portions of the vessel **104** in the second or subsequent layers absorb energy that has passed through the initial layer of coils, thereby providing a more efficient means of heating.

[0022] It should also be noted that the length of the chamber **100**, and the corresponding vessel **104**, was chosen for this system to accommodate a commercially available infrared lamp. Other lamps with other power ratings may be longer or shorter than the chosen lamp. It will be apparent to one of ordinary skill in the art after reading this disclosure that the chamber **100** and the vessel **104** can readily be made longer or shorter by appropriately cutting the extrusion to accommodate various lengths of lamps.

[0023] FIG. 3 shows a cross sectional schematic view of one embodiment. The vessel **104** is wound around the radiant energy source **103** in a heat exchange relationship

with the vessel **104** within the chamber **100**. Because of the small volume of fluid passing through the vessel **104** and the length of time in which the fluid remains in a heat exchange relationship with the fluid due to the coiling of the vessel **104** around the radiant energy source **103**, it is possible to control the output temperature of a fluid in steady state flow to within a 0.1 degree Celcius tolerance. In addition, it is possible to start the heater from a stopped condition and to have the fluid leaving the outlet end **102** to be within 1 degree Celcius of the desired temperature.

[0024] Another feature of this invention is the control circuit used in adjusting the temperature of the fluid to be heated. In the preferred embodiment, a programmable temperature/process controller is attached to the outlet end **102**. The controller monitors the temperature of the fluid at the outlet end **102** and compares it to a target value. If the deviation between the actual temperature and the target temperature varies more than an allowable amount, a signal is sent to the radiant energy source **103** whereby the power to the radiant energy source **103** may be increased or decreased to effect a change in the temperature of the fluid to be heated. In addition, deviations in the temperature may signal a defective radiant energy source **103**, thereby allowing for repair or replacement with minimal downtime.

[0025] While the present system and method has been disclosed according to the preferred embodiment of the invention, those of ordinary skill in the art will understand that other embodiments have also been enabled. Such other embodiments shall fall within the scope and meaning of the appended claims.